CS32 Discussion
Week 4

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Outline

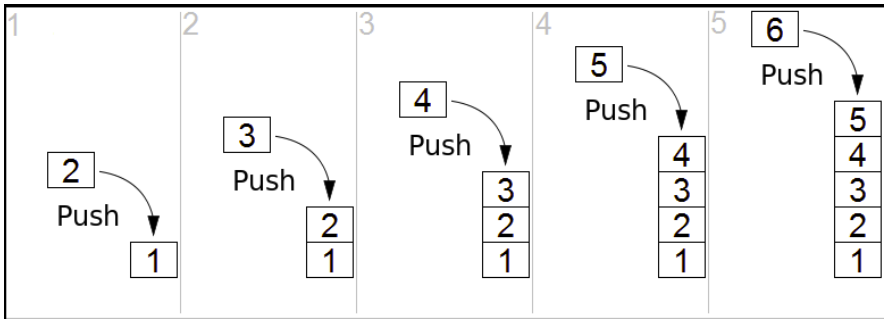
- Stack & Queue
- Inheritance
- Polymorphism

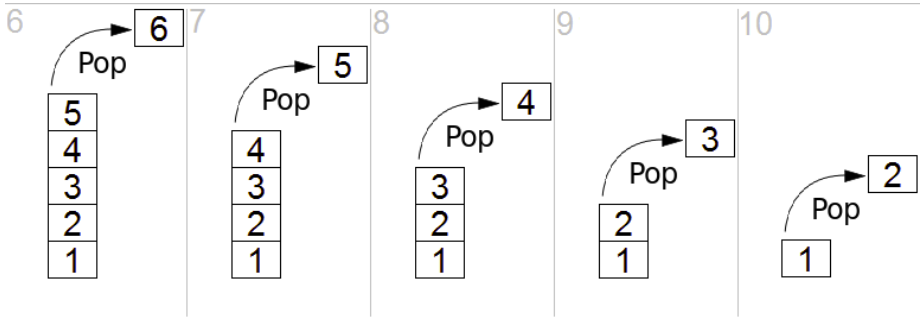
Stack and Queue

Stack (FILO)

```
class Stack
{
    public:
        bool push(const ItemType& item); // true if successful
        ItemType pop();                  // pop
        bool empty() const;              // true if empty
        int  count() const;              // number of items
    private:
         // Some data structure that keeps the items.
};
```

Stack Interface





Applications of Stack

- Stack memory: that's how function-call works.
- Compiling mathematical expressions: infix expression, matching brackets
- Depth-first-search

Implementation of Stacks

- Container: *linked list, (*or *dynamic array)*.
- If linked list:
  - Push: Insert node before head.
  - Pop: remove head.
  - Top: read head.
- Count() \ size(): online maintain (with a member variable).

Queue (FIFO)

```
class Queue
{
    public:
        bool enqueue(const ItemType& item); // push
        ItemType dequeue();                 // pop
        bool empty() const;                 // true if empty
        int  count() const;                 // number of items
    private:
         // some data structure that keeps the items
};
```

Queue Interface

Applications of Queues

- Windowed data streams.
- Process scheduling (Round Robin)
- Breadth-first-search

Implementation of Queues

- Container: *linked list* with a *tail* pointer.
- Enqueue: Insert node after tail.
- Dequeue: remove head.
- Front(), back(): read head / read tail
- Count() \ size(): online maintain (with a member variable).

Deque – double-ended queue

```
class Deque
{
 public:
 bool push_front(const ItemType& item);
 bool push_back(const ItemType& item);
 bool pop_front(const ItemType& item);
 bool pop_back(const ItemType& item);
 bool empty() const; // true if empty
 int count() const; // number of items
private:
! ! // Some data structure that keeps the items.
};
```

Implementation

- Standard library uses dynamic array as its container
  - We can also use doubly linked list.
- STL also uses deque as the container of stack and queue class under some configurations.

Question

- How to implement a queue with two stacks?

Solution

```
class Queue<E>
{
   public:
   void enqueue(E item) {
      inbox.push(item);
   }

   E dequeue() {
      if (outbox.isEmpty()) {
         while (!inbox.isEmpty()) {
            outbox.push(inbox.top());
            inbox.pop();
         }
      }
      E rst = outbox.top()
      outbox.pop();
      return rst;
   }
   private:
   Stack<E> inbox, outbox;
};
```

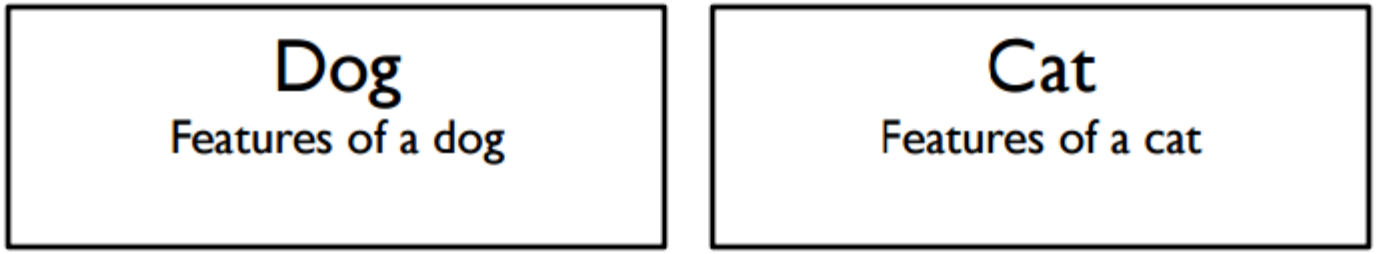
Stack, Queue, and Deque in C++ STL

- http://www.cplusplus.com/reference/stack/stack/
- http://www.cplusplus.com/reference/queue/queue/
- http://www.cplusplus.com/reference/deque/deque/

Inheritance

Inheritance

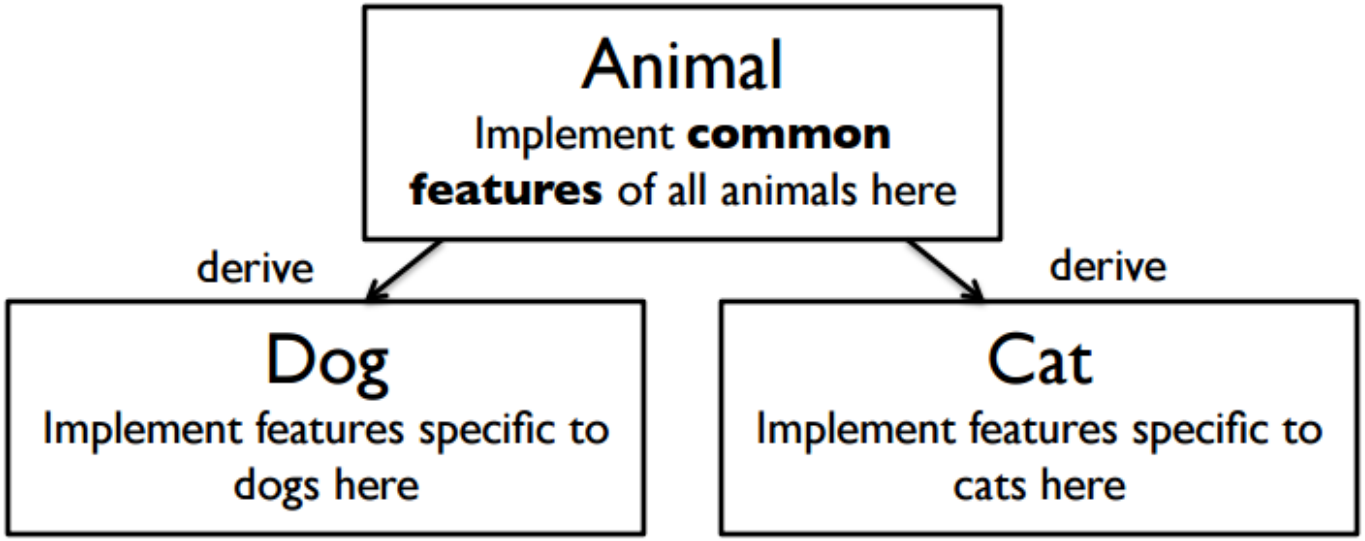
- The process of deriving a new class using another class as a base.
- Our example:



- But there might be some common features in the two…

Inheritance

- The process of deriving a new class using another class as a base.
- Our example:



Deriving a class from another

```
class Animal
{
  public:
    Animal();
    ~Animal();
    int getAge() const;
    void speak() const;
  private:
    int m_age;
};
```

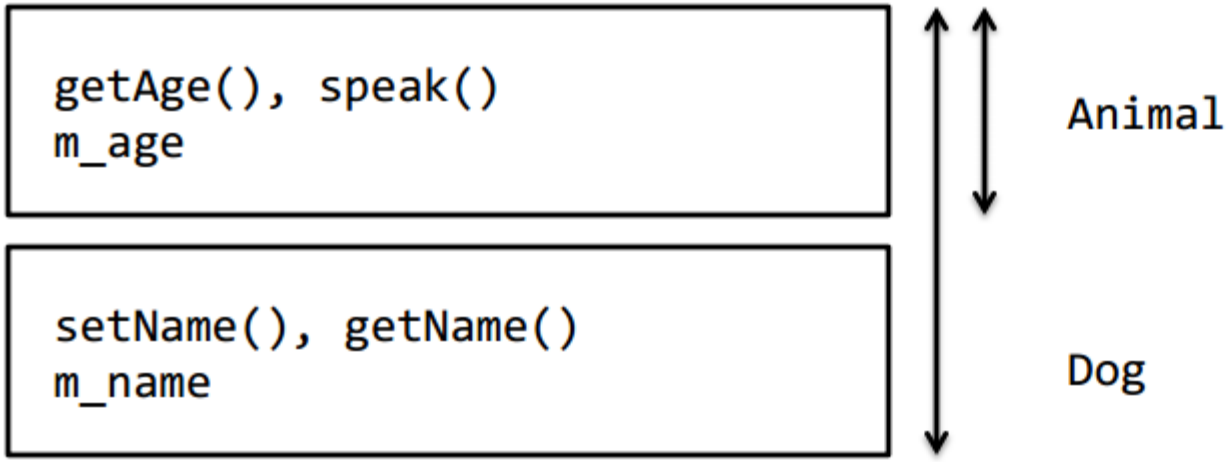
base class

```
class Dog : public Animal
{
  public:
    Dog();
    ~Dog();
    string getName() const;
    void setName(string name);
  private:
    string m_name;
};
```

derived class

- Dog inherits `Animal`.

Deriving a class from another




```
Dog d1;
d1.setName("puppy");
d1.getAge();
d1.speak();
```

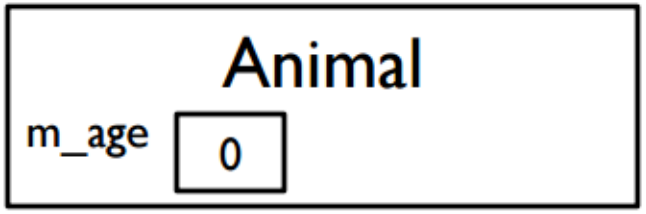
```
Animal a1;
a1.speak();
~~a1.setName(“abc”);~~
```

Deriving a class from another

- What's inherited:
  - all member functions except the overloaded assignment operator (`operator=`), constructors, and the destructor
  - all member variables
- However, the derived class cannot access the private members of the base class directly (e.g. Dog cannot access `m_age`).
- `class D : public B`
  - a D object is a kind of B
  - a D is a B (a Dog is an Animal)

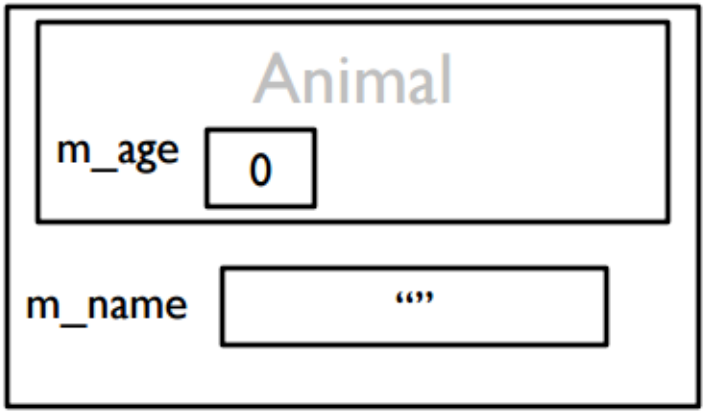
Construction

- So, a Dog is an Animal. What happens when we construct a Dog?
- 1. The base part of the class (Animal) is constructed.



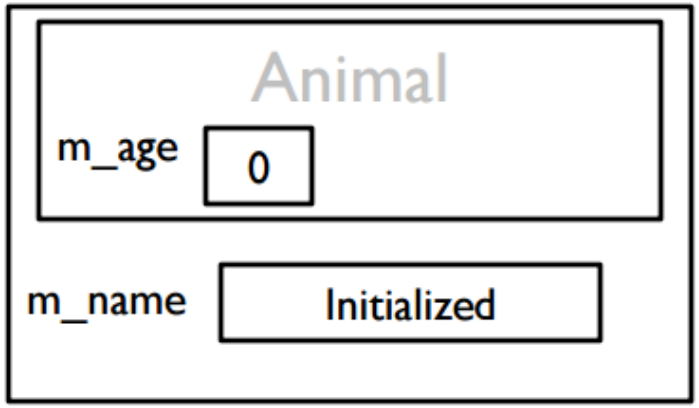
Construction

- So, a Dog is an Animal. What happens when we construct a Dog?
- 2. The member variables of Dog are constructed.



Construction

- So, a Dog is an Animal. What happens when we construct a Dog?
- 3. The body of Dog's constructor is executed.

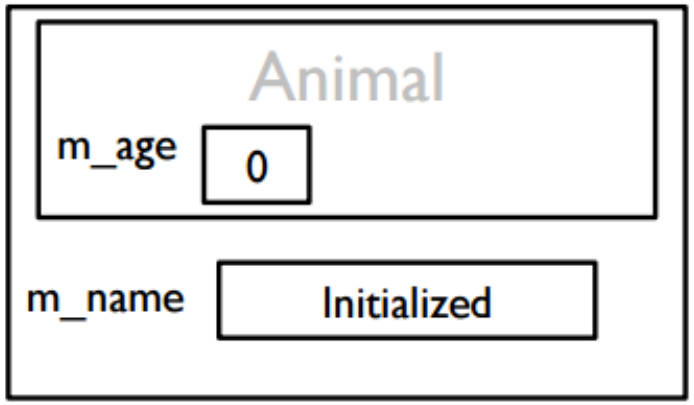


Construction

- Suppose I want to overload Dog's constructor to create:

```
Dog(string initName, int initAge);
```

- How would I go about implementing it?

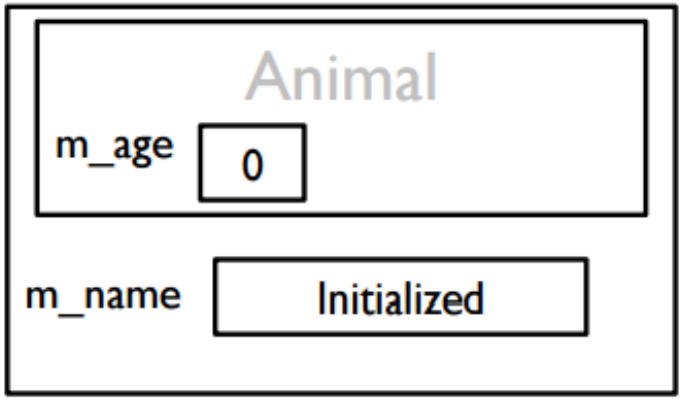


Construction

- Suppose I want to overload Dog's constructor to create:

```
Dog::Dog(string initName, int initAge)
: m_age(initAge), m_name(initName)
{}
```

Incorrect

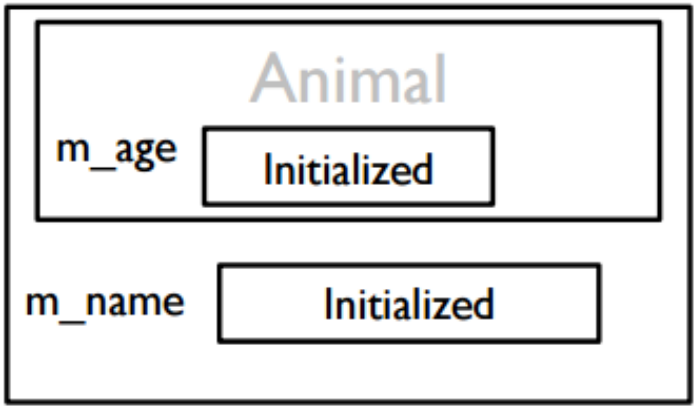


Construction

- Suppose I want to overload Dog's constructor to create:

```
Dog::Dog(string initName, int initAge)
: Animal(initAge), m_name(initName)
{}

class Animal
{
  public:
    Animal(int initAge);
    ...
};
```



Destruction

- Just reverse the order of construction.
- 1. The body of destructor is executed.
- 2. The member variables are removed.
- 3. The base part of the class is destructed.

Overriding member functions

- Assume `speak()` is implemented as follows.

```
void Animal::speak() const
{
  cout << "..." << endl;
}
```

- Dog inherits this function.
- But we want our Dog to really say something when ordered to speak!

Overriding member functions

```
class Dog : public Animal
{
  public:
    Dog();
    ~Dog();
    string getName() const;
    void setName(string name);
    void speak() const;
  private:
    string m_name;
};

void Dog::speak() const
{
  cout << "Woof!" << endl;
}
```

```
Animal a1;
a1.speak();
```

- Output

  ...

```
Dog d1;
d1.speak();
```

- Output

  Woof!

Overriding member functions

```
class Dog : public Animal
{
  public:
    Dog();
    ~Dog();
    string getName() const;
    void setName(string name);
    void speak() const;
  private:
    string m_name;
};

void Dog::speak() const
{
  cout << "Woof!" << endl;
}
```

- Why do we call this **overriding**, not **overloading**?

Overriding member functions

```
class Dog : public Animal
{
  public:
    Dog();
    ~Dog();
    string getName() const;
    void setName(string name);
    void speak() const;
  private:
    string m_name;
};

void Dog::speak() const
{
  cout << "Woof!" << endl;
}
```

- Why do we call this **overriding**, not **overloading**?
- Overload – same function name, but different return type and/or different set of arguments
- Override – same function name, same return type, same everything, except defined "again" in the derived class.

Overriding member functions

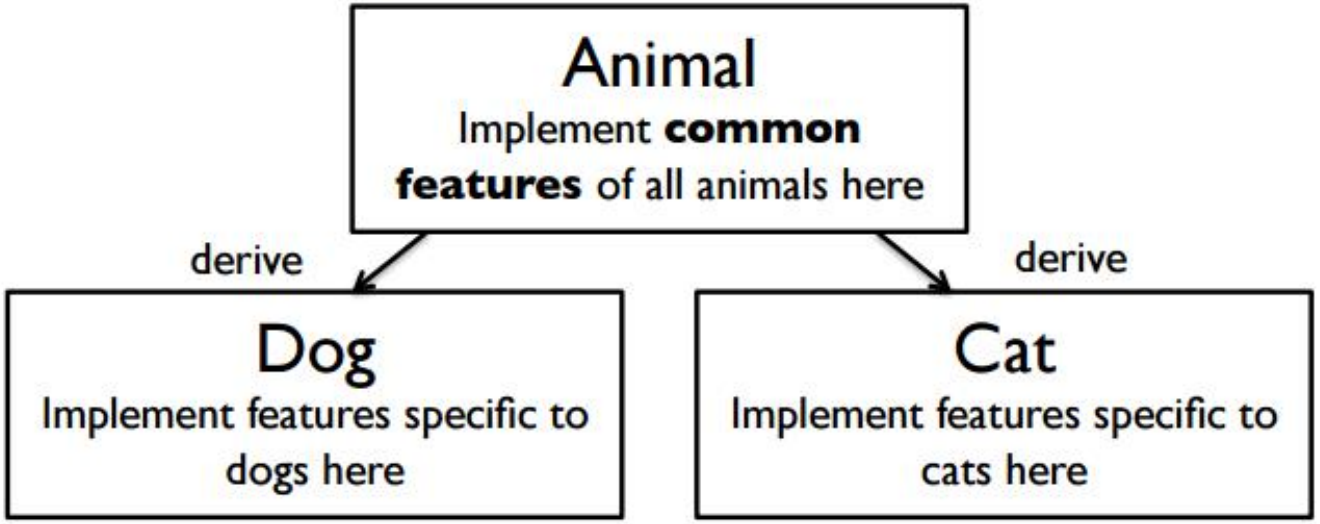
- Can I still call the base class's `speak()` on a Dog object?
- Yes, just do:

```
Dog d1;
d1.Animal::speak();
```

Polymorphism

Virtual functions: Motivation

- Back to this diagram:



- Suppose we have `speak()` overriden in `Cat`, where it goes "`Meow!`";

Virtual functions: Motivation

- C++ allows a pointer to the base class to point to a derived class.

- What do you think

  `pAni->speak();`

  will do?

  should do?

```
Animal *pAni;
int x;
cin >> x;

switch (x)
{
  case 1:
    pAni = new Dog;
    break;
  case 2:
    pAni = new Cat;
    break;
  default:
    pAni = new Animal;
    break;
}
```

Virtual functions: Motivation

- What it will do:
  "…", no matter what x is.
- What it should do:
  "Woof!" if x == 1,
  "Meow!" if x == 2,
  "…" otherwise

- We want the overriden function to be called!

```
Animal *pAni;
int x;
cin >> x;

switch (x)
{
  case 1:
    pAni = new Dog;
    break;
  case 2:
    pAni = new Cat;
    break;
  default:
    pAni = new Animal;
    break;
}
```

Virtual functions

```
class Animal
{
  public:
    Animal();
    virtual ~Animal();
    int getAge() const;
    virtual void speak() const;
  private:
    int m_age;
};
```

base class

```
class Dog : public Animal
{
  public:
    Dog();
    ~Dog();
    string getName() const;
    void setName(string name);
    void speak() const;
  private:
    string m_name;
};
```

derived class

- pAni->speak();

Will use the appropriate version of speak() according to the class of the pointee.

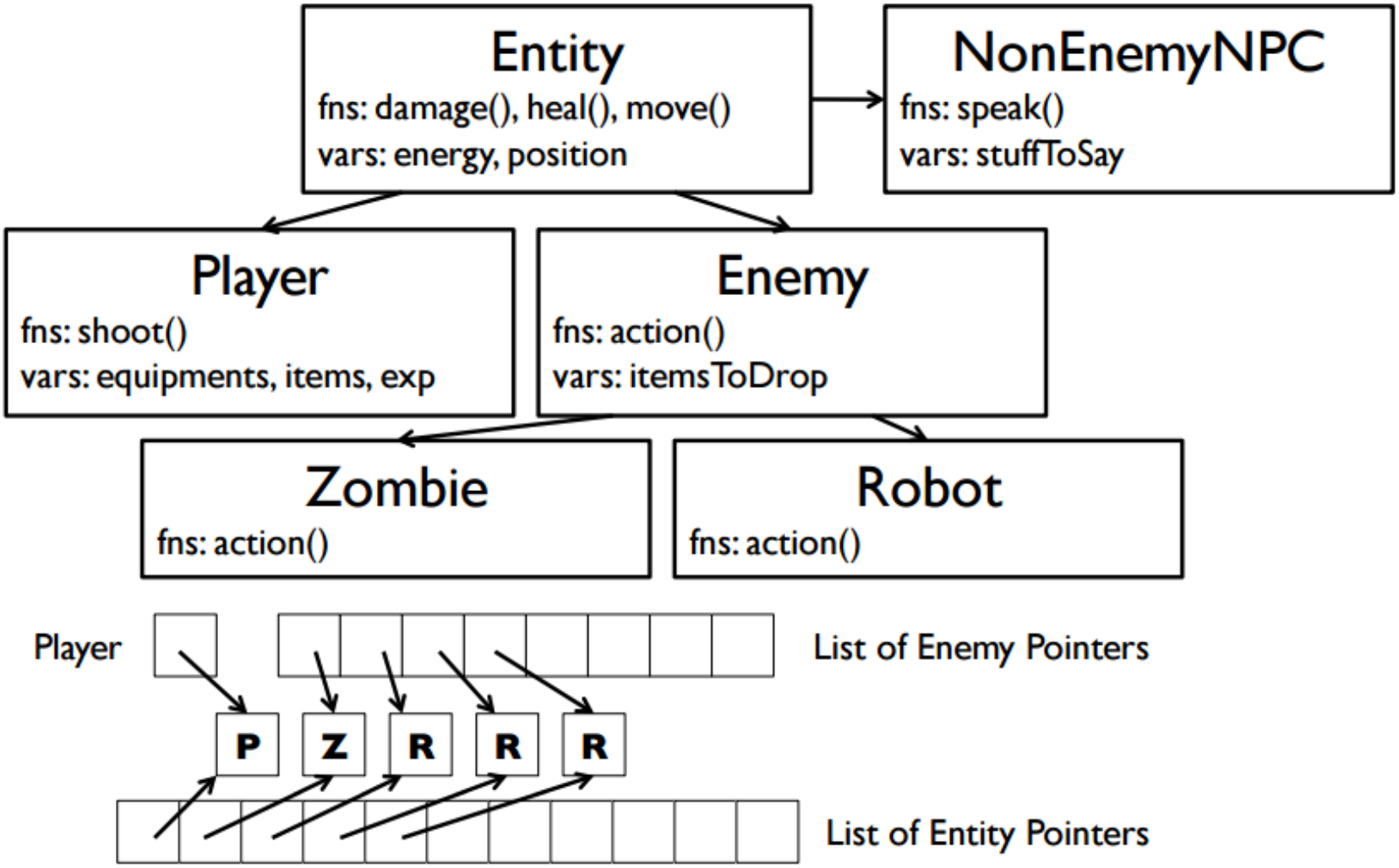
Polymorphism

- Late binding / dynamic binding
  - The appropriate version is selected during runtime!
- Polymorphism
  - pAni can take multiple forms.

```
Animal *pAni;
int x;
cin >> x;

switch (x)
{
  case 1:
    pAni = new Dog;
    break;
  case 2:
    pAni = new Cat;
    break;
  default:
    pAni = new Animal;
    break;
}
```

Polymorphism: a realistic example



Virtual functions

```
class Animal
{
  public:
    Animal();
    virtual ~Animal();
    int getAge() const;
    virtual void speak() const;
  private:
    int m_age;
};
```

base class

```
class Dog : public Animal
{
  public:
    Dog();
    ~Dog();
    string getName() const;
    void setName(string name);
    void speak() const;
  private:
    string m_name;
};
```

derived class

- Wait, what's that `virtual` doing before the destructor of Animal?

Animal speaks?

- speak is a common feature among all (or many) animals.
- But it really means something only if we know what this animal is.
- Option 1:
  - Get rid of `speak()` function in Animal, and implement it in all the derived classes.
    - Then we can't do `pAni->speak()`…
- Option 2:
  - Make it a **pure virtual function**.

Pure virtual functions

- You declare it in the base class, but don't define it, and add "= 0" in the declaration.
- It is a *dummy* function.
- The derived class **must** implement all the pure virtual functions of its base class.

```
class Animal
{
  public:
    Animal();
    virtual ~Animal();
    int getAge() const;
    virtual void speak() const = 0;
  private:
    int m_age;
};
```

Abstract base class

- If a class has at least one pure virtual function, it is called an **abstract base class**.

```
Animal a1;                          // won't compile
Animal *pAni = new Animal;          // won't compile
Animal *pAni = new Dog;             // still works
```

- Animal is like a "common" interface without complete implementation. Or, one can think of it as a "framework."

Bugs in your software are actually special features :)